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12a. DISTRIBUTION/AVAILABILITY STATEMENT
This document has been approved for public release and sale; its distribution is unlimited.

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13. ABSTRACT *(Maximum 200 words)*

The goal of this project was to develop methods for automated analysis of zooplankton size and taxonomic composition using images from the Video Plankton Recorder (VPR). Our three main objectives are to: 1) use our existing hardware to develop methods for detecting, in real time (60 fields per second, fps), the presence of in-focus organisms on the video and storing the images to disk, 2) develop pattern recognition software for classification of organisms into major taxonomic groupings (copepods, chaetognaths, doliolids, etc.), and 3) develop specifications for transferring the software routines to hardware to enable real-time sorting of zooplankton according to major taxa. The first objective was accomplished in year 1 and significant progress was made on the second two objectives in year 2. Our new 3-year grant which begins 1/1/95 will allow us to complete objectives 2 and 3 and develop a system for real-time visualization of planktonic taxa distributions while at sea.

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Final Report for ONR Grant N00014-93-1-0602 entitled:

Automated Analysis of Zooplankton Size and Taxonomic Composition using the Video Plankton Recorder

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II. Narrative Documentation:

A. Goals:

The goal of this project was to develop methods for automated analysis of zooplankton size and taxonomic composition using images from the Video Plankton Recorder (VPR). Ultimately, the system will sort plankton to species level and measure body size at sea in real-time. The VPR provides sharply focussed video images of plankton and seston in the size range 100 microns to 5 cm and has an on-board CTD, fluorometer, flowmeter, and transmissometer. Currently the VPR is towed at 0.5–3 m/s and has been deployed in shelf and oceanic waters including extensive survey work on Georges Bank. The VPR has also been deployed on ROV JASON for individual particle tracking, and a moored profiling system has been proposed which will include on-board image processing and satellite telemetry of processed data.

B. Objectives:

Our three overall objectives are to: 1) use our existing hardware to develop methods for detecting, in real time (60 fields per second, fps), the presence of in-focus organisms on the video and storing the images to disk, 2) develop pattern recognition software for classification of organisms into major taxonomic groupings (copepods, chaetognaths, doliolids, etc.), and 3) develop specifications for transferring the software routines to hardware to enable real-time sorting of zooplankton according to major taxa. Development of the complete image processing package will enable incorporation into the VPR system for real-time identification of planktonic taxa while at sea. The first objective was accomplished in year

1 and the second two objectives were addressed in year 2. Our new 3-year grant which begins 1/1/95 will allow us to complete objectives 2 and 3.

C. Approach:

Our approach for the first objective was to develop software for accurate focus detection and then transfer it to our IT-151 image processor. The approach for the second objective is to develop software for identification and sorting organisms to major taxa. The third objective involved establishing specifications for hardware that will operate the identification and sorting software in real-time.

D. Tasks Completed:

We have achieved of the first objective, i.e., real-time focus detection, and we have a good start on the identification problem. We now have a semi-automated system that we can use to determine plankton distributions at-sea in near-real-time.

E. Results:

Progress on objective 1, focus-detection and image storage, has been completed. We have developed focus-detection algorithms that are 99accurate, and we have implemented them in hardware using our Imaging Technology 151 real-time image processor interfaced to a SUN SPARCstation 10. The hardware system consists of a video output device (tape player or live from camera) that sends the video plus time code overlay to both the IT-151 as well as to a time-code reader (Horita Inc.) which are both connected to the SUN SPARCstation. An algorithm has been developed to read the video time-code (field accurate) in real time from the time-code reader into the SUN. We have prototyped several techniques using the IT-151 pipeline processor for real-time presence-absence and region-of-interest detection of particles and for sending selected streaks from the regions-of-interest to the SUN for focus detection. The in-focus regions-of-interest are sent from the IT-151 to the SUN hard-disk and compressed to Exabyte tape for storage.

Objective 2 – classification based on taxonomy and size, was supposed to be addressed after the focus-detection system was in place. Nonetheless, we made considerable progress in this area. We are advancing rapidly in our identification capabilities, since we have a team of experts in gray-scale pattern recognition working on the problem, and the basic methods have been used in industrial and medical applications for some time now. We have already used several classification schemes (Bayes discriminant, K-Nearest Neighbor rule, and a BP neural network) to classify four groups of zooplankton (copepod, doliolids, Trichodesmium, and pteropods). These average around 90% accurate using a hybrid feature vector consisting of moment invariants, shape factors, and 1st and 2nd order intensity statistics. Once the training sets and related software are established, the focus, sizing, and identification algorithms will allow completely automated analysis of VPR images. We are in the process of developing specifications for hardware needed for real-time processing of the VPR images as they are acquired at sea. As an interim, we have developed point-and-click software for analyzing the regions of interest for size and taxonomy.

We now have developed the capability for real-time focus detection. This rapid automated culling of blank and out-of-focus images reduces processing time of the video by over a

factor of 50. This focus detection system coupled with our point-and-click user interface allows near-real-time analysis of zooplankton distributions at sea. We used this system on our May GLOBEC cruise to Georges Bank to observe the 3-D distribution of the copepod Calanus finmarchicus in a 2x2 km grid.

F. Impact

The ability to visualize the distribution of planktonic taxa (and size structure) at sea in real time will revolutionize the study of pelagic biology. No longer will we be probing in the dark, only able to analyze the data once samples have been analyzed in the laboratory months or years later. The dynamical nature of the pelagic environment necessitates the use of tools which can provide rapid visualizations of plankton distributions together with physical properties of the water. The system we are developing provides this capability.

G. Transitions

The real-time sampling system can be used in any studies in which it is desirable to measure plankton abundance including sound and light scattering studies and ecological studies of environmental quality and fisheries ecology.

H. Relationships to other projects:

The video processing procedures we have developed are closely coupled to our NSF - NOAA funded research on Georges Bank (GLOBEC) and our NSF funded development of a vertically profiling VPR. We also have proposed to use the VPR to map plankton abundance and hydrography in the vicinity of the new Boston Harbor outfall in Massachusetts Bay.

III. STATISTICAL INFORMATION:

A. List of ONR sponsored publications:

Davis, C. S., S. M. Gallager, M. Marra, and W. K. Stewart. Rapid visualization of plankton abundance, size, and taxonomic composition using the Video Plankton Recorder. Deep Sea Res. (in draft)

Benfield, M. C., C. S. Davis, P. H. Wiebe, S. M. Gallager, R. G. Lough, and N. J. Copley. Comparative distributions of calanoid copepods, pteropods and larvaceans estimated from concurrent Video Plankton Recorder and MOCNESS tows in the stratified region of Georges Bank. Deep Sea Res. (submitted)

Flierl, G. R. and C. S. Davis. Reduction of complexity in coupled biological-physical models. J. Mar. Res. (submitted)

Gallager, S. M., C. S. Davis, and A. Epstein. High-resolution spatial distributions of plankton correlated with hydrography in Great South Channel using the Video Plankton Recorder. Deep Sea Res. (submitted).

Kleppel, G. S., C. S. Davis, and K. Carter. Temperature and copepod growth in the sea: a comment on temperature dependence. Am. Nat., (in press).

Norrbin, M. F., C. S. Davis, and S. M. Gallager. Differences in structure and composition of zooplankton between mixed and stratified regions of George's Bank. Deep Sea Res. (submitted).

Zeldis, J. R., C. S. Davis, M. R. James, S. L. Ballara, W. E. Booth, and F. H. Chang. Salp grazing in a larval fish habitat: effects on phytoplankton abundance, vertical distribution, and species composition. Mar. Ecol. Prog. Ser., (in press).

Davis, C. S. and J. H. Steele. 1994. Modeling upper ocean biological-physical processes. URIP Workshop Report, WHOI TECH RPT 94-32, 65 pp.

Lewis, C. V., C. S. Davis, and G. Gawarkiewcz. 1994. Wind-forced biological-physical dynamics on an isolated off-shore bank. Deep-Sea Res. 41, 51-73.

Vincent, L. 1994. Fast opening functions and morphological granulometries. SPIE Vol. 2300, Image Algebra and Morphological Image Processing V, pp 253-267.

Vincent, L. 1994. Fast grayscale granulometry algorithms. EURASIP Workshop ISMM '94, Mathematical Morphology and its Applications to Image Processing, Kluwer Academic Publishers, Serra, J. and P. Soille,(eds), pp. 265–272.

Flierl, G. R. and C. S. Davis. 1993. Biological effects of Gulf Stream meandering. J. Mar. Res., 51, 529-560.

B. Number of grad students 1 - Craig Lewis

C. Patents none

D. Presentations

Davis, C. S., S. M. Gallager, and P. Alatalo. 1994. Vernal Stratification and Fine-scale Distributions of Zooplankton on Georges Bank as determined by the Video Plankton Recorder. EOS 75 (3). AGU Ocean Sciences Meeting, San Diego, March, 1994

Davis, C. S. P. H. Wiebe, S. M. Gallager, A. W. Epstein, J. R. Green, M. S. Berman, L. J. Buckley, R. G. Lough, L. Incze, M. C. Macaulay. 1994. Intercomparison of Zooplankton Sampling Methods During the GLOBEC/MER Georges Bank Study in May 1992. EOS 75 (3). AGU Ocean Sciences Meeting, San Diego, March, 1994

Davis, C. S. and S. M. Gallager. 1994. The Video Plankton Recorder: System Components and Deployment Configurations EOS 75 (3). AGU Ocean Sciences Meeting, San Diego, March, 1994

Gallager, S. M., C. S. Davis, and A. Epstein. 1994. High resolution spatial distributions of holo-and mero-plankton correlated with hydrography in Great South Channel, Georges Bank, as determined by the Video Plankton Recorder. EOS 75 (3). AGU Ocean Sciences Meeting, San Diego, March, 1994

Norrbin, M. F., C. S. Davis, and S. M. Gallager. 1994. Spatial structure of plankton populations on the southern slope of Georges Bank: biological and physical causes. EOS 75 (3). AGU Ocean Sciences Meeting, San Diego, March, 1994

Davis, C. S., P. Alatalo, and C. V. Lewis. 1993. Zooplankton Size-Structure and Taxonomic Composition in a Gulf Stream Meander. Abstract of paper presented at TOS, April, 1993.

Olson, D. B., C. S. Davis, G. Peng, and G. R. Flierl. Plankton dynamics in a meandering mesoscale jet. TOS, April, 1993

E. Committees

NSF Ocean Sciences Strategic Plan for Research and Education, Participated in development of NSF OCE's 10-Year plan for research and education.

NSF GLOBEC Georges Bank Program Executive Committee

ONR URIP program steering committee

F. Honors and awards

Davis Awarded Tenure, Stewart promoted to Associate Scientist, Gallager promoted to Assistant Scientist